

capable of removing the smallest droplets, but also must resist becoming flooded by the largest droplets and releasing the collected liquid as entrained water.

The USNRC recommends the use of entrainment separators for engineered safety systems when the air may be carrying entrained liquid droplets or a cooling and condensing vapor.<sup>36</sup> Although HEPA filter paper is treated for water repellency, high water loadings rapidly saturate the paper and raise its airflow resistance to a point where gross holes can result. Hot water and steam cause paper to lose its strength and to fail even more rapidly. Therefore, the criteria for entrainment separators used for nuclear service call for (1) at least 99.9 percent retention by weight of entrained water and condensed steam in the size range 1 to 2,000  $\mu\text{m}$  at a delivery rate of 1 L/m<sup>3</sup>; (2) at least 99 percent retention by count of droplets in the 1- to 10- $\mu\text{m}$ -diameter range; (3) no flooding or water re-entrainment under the above operating conditions; and (4) a temperature tolerance at least to 160 degrees Celsius. An entrainment separator with these characteristics will provide long-term protection for a downstream HEPA filter that would be destroyed in a few minutes without it. Entrainment separators are usually constructed of deep layers of high-porosity metal and glass fibers, either packed or woven into stable batts, and arranged in graded sizes and packing density to give the desired small droplet collection capability with excellent resistance to flooding and re-entrainment.

### 3.7 FILTER SELECTION

Nuclear-grade HEPA filter papers are distinguished from otherwise identical products by their proven resistance to deterioration by radiation. This requirement is spelled out in ASME AG-12, which calls for 50 percent retention of original strength and water repellency after exposure to an integrated dose of 6.0 to 6.5 x 1 to 7 rads at a dosage rate not to exceed 2.5 mrad/hr. Because all fabricated filters destined for nuclear service will contain identical or equivalent paper, selection can be based solely on the type of filter construction.

Deep-pleat filters with corrugated aluminum separators have dominated nuclear service both by

numbers and years of use, and therefore have the longest and most thoroughly documented performance record. They appear to be stronger than other filter designs, although mini-pleat and separatorless filters are able to meet existing strength requirements in applicable filter standards. Mini-pleat construction has the desirable advantage of packing twice as much paper into a given volume of filter. A disadvantage of the mini-pleat design is the narrowness of the air passages between adjacent pleats, which make it susceptible to premature clogging of the openings by large particles and fibers. This may not be a difficulty when the air being filtered is exceptionally dust-free or when efficient prefilters are employed. Nuclear service experience is sparse or totally lacking for types of filter construction other than deep-pleat filters with corrugated separators, although there may be equivalent experience in nonnuclear applications.

Special nuclear filters are needed when service conditions involve exceptional physical or chemical stress. Although the usual run of filters for nuclear service must provide resistance to short-term exposure to heated air and flame, they are not designed for long-term operation at temperatures exceeding 120 degrees Celsius (248 degrees Fahrenheit). Because the organic sealant between filter pack and filter frame is the least temperature-resistant component, it is possible to increase temperature resistance by substituting a tightly compressed fine-fiber batt for the organic adhesive. In addition, substituting a metal frame for a plywood or composition board increases temperature resistance to the melting point of the glass fibers in the filter medium [500 degrees Celsius (932 degrees Fahrenheit)]. Before this temperature is reached, the organic binder and water-repellent chemicals in the paper will be lost, but this does not adversely affect filtration efficiency or airflow resistance.

The chemical resistance of low-temperature nuclear filters is generally excellent for all dry gases. With high humidity, the presence of HF will cause etching and embrittlement of the glass fibers and ultimate failure of the filter. When droplets of HF or condensed water plus HF gas are present in the airstream, rapid failure of the glass filter paper may be anticipated. Rapid failure (within hrs) also occurs when hygroscopic salts

from chemical processing collect on the filter surface and form a moist, slush-like cake that absorbs HF and infiltrates the pores of the filter paper. Special filter papers have been formulated with 7 percent Nomex fibers to provide extra chemical resistance for this type of service.

Aluminum separators are especially susceptible to chemical attack by many substances other than HF. United States requirements call for vinyl-epoxy coatings of 0.2 to 0.3  $\mu\text{m}$  in thickness on both the sides and edges of aluminum separators when the presence of acid is predicted. Stainless steel separators are a more costly alternative.

Deep-bed filters of sand, gravel, and crushed stone do not compete directly with HEPA filters, except at a few installations involved in chemical operations associated with fuel reprocessing, but they have recently come under intense study as a means of mitigating core meltdown events by providing a filtration capacity for venting containment vessel overpressures and for coping with a possible hydrogen burn inside the containment. DBS filters have also been studied extensively for a potential role in mitigating loss of coolant accidents for metal-cooled reactors.

### 3.8 REFERENCES

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